Docket No. - GMC 0047 PA

SPATIALLY VARYING DIFFUSION MEDIA AND DEVICES INCORPORATING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to commonly assigned U.S. Patent Application Serial Nos. __/___,___ (GP 303 569 / GMC 0048 PA), filed ________________ and __/___,___ (GP 303 447 / GMC 0051 PA) filed _______________, the disclosures of which are incorporated herein by reference. The present application is also related to commonly assigned U.S. Patent Application Serial No. __/___,___ (GP 302 361 / GMC 0011 PA), filed ________________.

BACKGROUND OF THE INVENTION

The present invention relates to the design and manufacture of diffusion media and, more particularly, to diffusion media for use in electrochemical cells where water management is a significant design issue.

BRIEF SUMMARY OF THE INVENTION

According to the present invention, a diffusion media and a scheme for spatially varying the parameters of the diffusion media to address issues related to water management in electrochemical cells and other devices employing the diffusion media are provided. In accordance with one embodiment of the present invention, a device is configured to convert a hydrogenous fuel source to electrical energy. The device comprises an electrochemical conversion assembly, first and second reactant inputs, first and second product outputs, and first and second diffusion media.

The electrochemical conversion assembly configured to partition the device into first and second flow field regions. The first reactant input and the first product output are in communication with the first flow field region, The first diffusion media comprises a porous diffusion media substrate configured to pass multiphase reactants between the first flow field region and the electrochemical conversion assembly. The second reactant input and the second product output are in communication with the second flow field region. The second diffusion

media comprises a porous diffusion media substrate configured to pass multiphase reactants between the second flow field region and the electrochemical conversion assembly.

The device is configured such that at least one of the first and second diffusion media comprise a region subject to relatively high H_2O concentrations and a region subject to relatively low H_2O concentrations. A mesoporous layer is carried along at least a portion of a major face of one of the first and second diffusion media substrates and comprises a hydrophilic carbonaceous component and a hydrophobic component. The mesoporous layer occupies a substantially greater portion of one of the high H_2O region and the low H2O region relative to the other of the high H_2O region and the low H2O region.

In accordance with another embodiment of the present invention, the mesoporous layer comprises a hydrophilic carbonaceous component and a hydrophobic component. At least one of the first and second diffusion media substrates comprises a relatively high porosity region and a relatively low porosity region. The relatively high porosity region of the substrate occupies a substantially greater portion of the high H_2O region and the relatively low porosity region of the substrate occupies a substantially greater portion of the low H_2O region.

Accordingly, it is an object of the present invention to provide a means for addressing water management issues in diffusion media and devices employing such diffusion media. Other objects of the present invention will be apparent in light of the description of the invention embodied herein.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The following detailed description of specific embodiments of the present invention can be best understood when read in conjunction with the following drawings, where like structure is indicated with like reference numerals and in which:

Fig. 1 is a schematic illustration of a fuel cell incorporating a porous diffusion media according to the present invention;

Figs. 2-9 are schematic illustrations of porous diffusion media according to various embodiments of the present invention; and

Fig. 10 is a schematic illustration of a vehicle incorporating a fuel cell according to the present invention.

DETAILED DESCRIPTION

Referring initially to Fig. 1 a fuel cell 10 incorporating a porous diffusion media 20 according to the present invention is illustrated. Specifically, the fuel cell 10 comprises an electrochemical conversion assembly in the form of a membrane electrode assembly 30 interposed between an anode flow field region 40 and a cathode flow field region 50 of the fuel cell 10. It is contemplated that the flow fields 40, 50 and the electrochemical conversion assembly may take a variety of conventional or yet to be developed forms without departing from the scope of the present invention. Although the particular form of electrochemical conversion assembly is beyond the scope of the present invention, in the illustrated embodiment, the electrochemical conversion assembly comprises a membrane electrode assembly 30 including respective catalytic electrode layers 32 and an ion exchange membrane 34.

The present invention is not directed to the specific mechanisms by which the fuel cell 10 converts a hydrogenous fuel source to electrical energy. Accordingly, in describing the present invention, it is sufficient to note that the fuel cell 10 includes, among other things, an electrochemical conversion assembly configured to partition the device into the first and second flow field regions 40, 50, and a first reactant input $R_{IN\,1}$ and a first product output $R_{OUT\,1}$ in communication with the first flow field region 40. The first diffusion media 20 comprises a porous diffusion media substrate 22 that passes multiphase reactants between the first flow field region 40 and the membrane electrode assembly 30. Similarly, a second reactant input $R_{IN\,2}$ and a second product output $R_{OUT\,2}$ are in communication with the second flow field region 50 and a second diffusion media 20 passes reactants between the second flow field region 50 and the membrane electrode assembly 30. For example, by way of illustration and not limitation, the first reactant input R_1 may carry a humidified hydrogenous fuel mixture to an anode side of the fuel cell 10, the second reactant input R_2 may carry a humidified oxidant mixture to the cathode side of the fuel cell 10, and the reactant outputs R_{OUT} may carry products of the reactions on each side of the fuel cell 10.

The present inventors have recognized that the water management properties of the diffusion media 20 should be spatially optimized across the diffusion media because the water demands vary across the diffusion media as a function of the amount of water handled by particular portions of the diffusion media 20. Specifically, a particular electrochemical

conversions device may be configured such that one or both of the diffusion media comprise a region that is subject to relatively high operational H_2O concentrations and a region that is subject to relatively low operational H_2O concentrations. For example, the region of a cathode side diffusion media proximate the second product output $R_{OUT\,2}$, e.g., the cathode exit, may be required to transfer a greater volume of water than the region proximate the second reactant input $R_{IN\,2}$, e.g., the cathode input. Similarly, the region of an anode side diffusion media proximate the first product output $R_{OUT\,1}$, e.g., the anode exit, may be operate under dryer conditions than the region proximate the first reactant input $R_{IN\,1}$, e.g., the anode input.

The diffusion media 20 illustrated in Figs. 2-9 present a means for addressing such water management issues. Specifically, referring Figs. 2 and 3, a mesoporous layer 24, which may be carried along either of the major faces 21, 23 of the diffusion media substrates 20, is positioned to occupy a substantially greater portion of either the high H_2O region (see Fig. 2) or the low H2O region (see Fig. 3). Referring to the embodiment of Fig. 2, where the mesoporous layer 24 occupies a substantially greater portion of, or is confined to, the high H_2O region, then the mesoporous layer should be configured to enhance H_2O transfer properties of the diffusion media substrate 22. Conversely, referring to the embodiment of Fig. 3, where the mesoporous layer 24 occupies a substantially greater portion of, or is confined to, the low H_2O region, then the mesoporous layer should be configured to diminish the H_2O transfer properties of the diffusion media substrate 22.

A variety of mesoporous layer parameters including porosity, thickness, degree of substrate infiltration, etc., may be optimized for either enhancing or diminishing water transfer properties of the layer. For example, the porosity of the mesoporous layer 24 may be generally higher when the layer is utilized in the high H_2O region, where increased wicking is required. In the case where the mesoporous layer 24 comprises a hydrophilic carbonaceous component and a hydrophobic component, the porosity of the layer 24 may be increased by providing about 80 wt% of the carbonaceous component when used in the high H_2O region, as compared to between about 90 wt% and about 95 w% of the carbonaceous component in the low H_2O region.

Suitable carbon particles for the mesoporous layer 24 include, for example, carbon black, graphite, carbon fibers, fullerenes and nanotubules. In addition to the high surface area carbon, the hydrophilic carbonaceous component of the mesoporous layer 24 may comprise a minor

portion of carbon graphite to enhance electrical conductivity. The hydrophobic component may comprise a fluorinated polymer, e.g., polytetrafluoroethylene (PTFE), polyvinylidene fluoride (PVDF), polyvinyl fluoride (PVF), a combination of fluorinated polymers, or any other suitable hydrophobic material or combination of materials.

In specific embodiments of the present invention, the hydrophilic carbonaceous component of the mesoporous layer 24 in the high H_20 regions may comprises a moderate surface area carbon characterized by a surface area of between about 60 m^2/g and about 300 m^2/g and a mean particle size of between about 15 nm and about 70 nm. Conversely, in the low H_2O regions, the hydrophilic carbonaceous component may comprise a high surface area carbon characterized by a surface area of above about 750 m^2/g and a mean particle size of less than about 20 nm. In other embodiments of the present invention, the mesoporous layer infiltrates the diffusion media substrate to a depth of less than 10μm when used in the high H2O regions and to a depth of less than 25μm when used in the low H2O regions.

Referring now to Fig. 4, a plurality of mesoporous layers 24A, 24B are carried along respective portions of a major face 21 of the diffusion media substrates 22. The mesoporous layer 24A is configured to enhance the H_2O transfer properties of the diffusion media substrate 22 and, as such, occupies the high H_2O region. Further, the mesoporous layer 24B is configured to diminish the H_2O transfer properties of the diffusion media substrate 22 and, as such, occupies a substantially greater portion of the low H_2O region. As a result, water will tend to be wicked away from the high H_2O region and retained in the low H_2O region - improving device performance.

Figs. 5-7 illustrate embodiments of the present invention where the mesoporous layer 24 is carried along a reduced thickness portion of the substrate 22. A substantially planar surface profile may be maintained in the diffusion media by ensuring that the difference in thickness of the substrate 22 introduced the reduced thickness portion of the substrate 22 is sufficient to accommodate for the increase in diffusion media thickness introduced by the mesoporous layer 22.

An alternative means for addressing water management issues across a diffusion media according to the present invention is illustrated in Fig. 8. In Fig. 8, a substantially uniform mesoporous layer is carried along the major face 21 of the diffusion media substrate 22 and the

diffusion media substrate 22 is provided with a relatively high porosity region 22A in the high H_2O region of the diffusion media and a relatively low porosity region 22B in the low H_2O region of the diffusion media.

The diffusion media substrate may comprise a carbonaceous fibrous matrix, e.g., carbon fiber paper and may be characterized by a porosity of above about 70% in the high H_2O regions and between about 70% and about 75% in the low H_2O regions. The substrate may define a thickness of between about 100µm and about 300µm in the high H_20 regions and a thickness of between about 190µm and about 300µm in the low H_20 regions. Further, the substrate may be characterized by a mean pore size of above about 20µm in the high H_20 regions and less than about 25µm in the low H_20 regions.

Referring finally to Fig. 9, the mesoporous layer 24 may be configured such that it occupies substantial portions of both the high H_2O region and the low H2O region. To address variations in water management demands across the diffusion media, the mesoporous layer 24 is provided with a region of increased porosity relative to a remaining portion of the mesoporous layer. Specifically, the region of increased porosity of the mesoporous layer 24 is defined by a plurality of megapores 26 formed in the layer 24. The region of increased porosity occupies the high H_2O region of the diffusion media while the remaining portion of the mesoporous layer 24 occupies the low H_2O region of the diffusion media. Although the particular dimensions associated with the megapores 26 will vary according to the specific demands of the application at issue, it is contemplated that suitable pore sizes will range from about 100µm to about 500µm.

In many embodiments of the present invention the mesoporous layer 24 is more effective in addressing water management issues if it is positioned against the membrane electrode assembly 30 of the fuel cell 10, as opposed to being positioned to face the flow field of the cell 10. Nevertheless, it is contemplated that the diffusion media substrate 22 may carry the mesoporous layer 24 along either major face 21, 23 of the substrate 22 regardless of which face is positioned against the membrane electrode assembly 30. Further, the mesoporous layer 24 at least partially infiltrates the diffusion media substrate 22. The extent of the depth of infiltration into the diffusion media substrate 22 will vary widely depending upon the properties of the mesoporous layer 24 and the diffusion media substrate 22. In some embodiments of the present invention, it may be advantageous to configure the mesoporous layer such that it is more porous

than the fibrous matrix of the diffusion media substrate. For the purposes of defining and describing the present invention, it is noted that mesoporous structures are characterized by pore sizes that can range from a few nanometers to hundreds of nanometers.

Referring now to Fig. 3, a fuel cell system incorporating diffusion media according to the present invention may be configured to operate as a source of power for a vehicle 100. Specifically, fuel from a fuel storage unit 120 may be directed to the fuel cell assembly 110 configured to convert fuel, e.g., H2, into electricity. The electricity generated is subsequently used as a motive power supply for the vehicle 100 where the electricity is converted to torque and vehicular translational motion.

It is noted that terms like "preferably," "commonly," and "typically" are not utilized herein to limit the scope of the claimed invention or to imply that certain features are critical, essential, or even important to the structure or function of the claimed invention. Rather, these terms are merely intended to highlight alternative or additional features that may or may not be utilized in a particular embodiment of the present invention.

For the purposes of describing and defining the present invention it is noted that the term "device" is utilized herein to represent a combination of components and individual components, regardless of whether the components are combined with other components. For example, a "device" according to the present invention may comprise a diffusion media, a fuel cell incorporating a diffusion media according to the present invention, a vehicle incorporating a fuel cell according to the present invention, etc.

For the purposes of describing and defining the present invention it is noted that the term "substantially" is utilized herein to represent the inherent degree of uncertainty that may be attributed to any quantitative comparison, value, measurement, or other representation. The term "substantially" is also utilized herein to represent the degree by which a quantitative representation may vary from a stated reference without resulting in a change in the basic function of the subject matter at issue.

Having described the invention in detail and by reference to specific embodiments thereof, it will be apparent that modifications and variations are possible without departing from the scope of the invention defined in the appended claims. More specifically, although some aspects of the present invention are identified herein as preferred or particularly advantageous, it

is contemplated that the present invention is not necessarily limited to these preferred aspects of the invention.

What is claimed is: